



WCOSS Science Quarterly
09 July 2015
Updated 12 Oct 2015



Rapid Refresh (RAP) v3.0

High-Resolution Rapid Refresh (HRRR) v2.0

NOAA/ESRL/GSD/EMB

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Rapid Refresh and HRRR NOAA hourly updated models

13km Rapid Refresh (RAP)

Version 2 -- NCEP
implemented 25 Feb 2014

Version 3 – GSD – start 1/1/2015

Planned NCEP – Early 2016

Larger Domain (red → white)

Longer Forecasts (18 → 30/24 hrs)

3km High Resolution Rapid Refresh (HRRR)

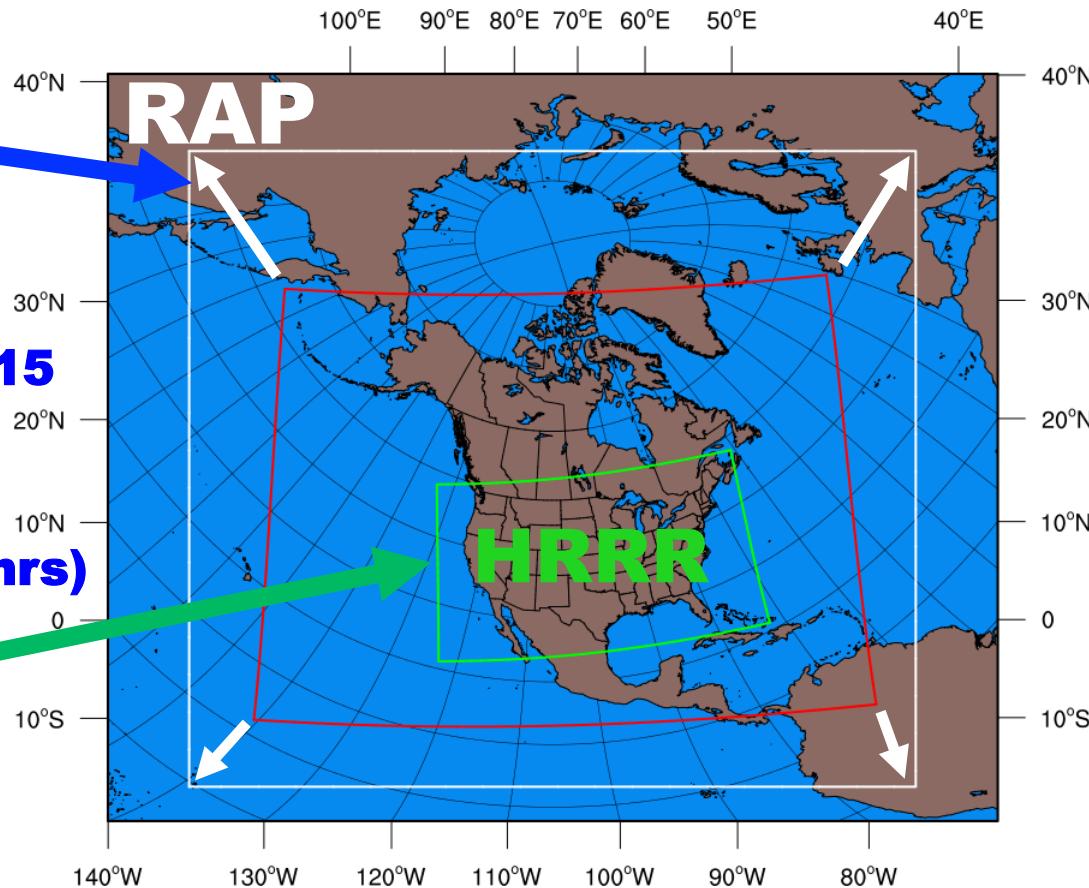
Initial – NCEP

implemented 30 Sept 2014

Version 2 – GSD – start 4/10/2015

Planned NCEP – Early 2016

Longer Forecasts (15 → 24/18 hrs)



Domain expansion to match 12km NAM.
Supports improved SREF initialization.



RAP and HRRR R2O Schedule

NCEP Operational Implementations

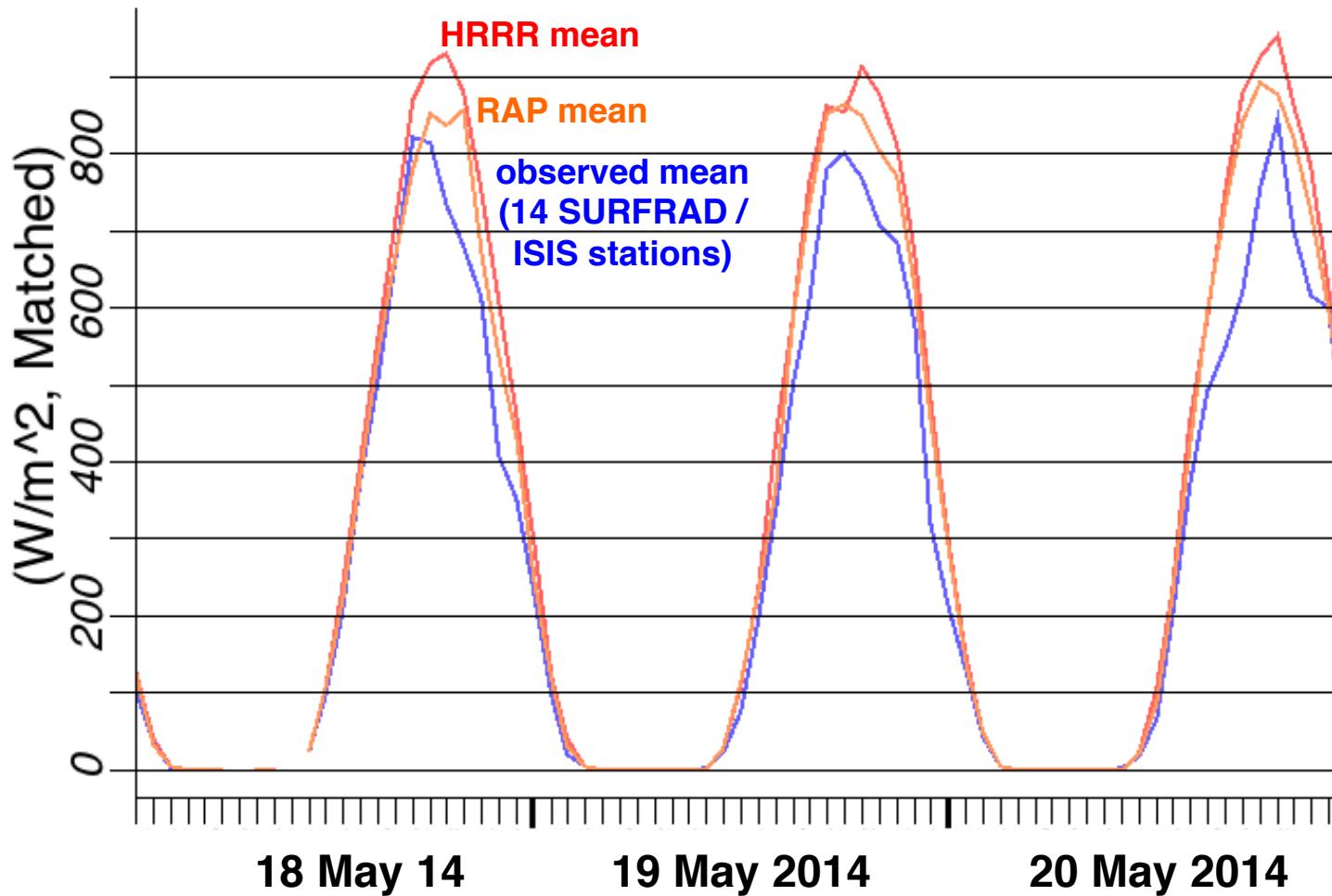
- May 2012 RAPv1: Adoption of GSI, WRF-ARW and unified post
 Enabled use of community-developed software
- Feb 2014 RAPv2: Hybrid DA
 Significant improvement in upper-air forecasts
- Sep 2014 HRRRv1: 3-km Radar DA in WRF-ARW
 Significant improvement in convective forecasts
- Feb 2016 RAPv3/HRRRv2:
 Aerosol Thompson MP, improvements to MYNN PBL,
 RUC LSM, RRTMG radiation, Grell-Freitas cumulus
 Significant improvement in surface/lower-trop forecasts



Cloud Deficiency in RAP and HRRR

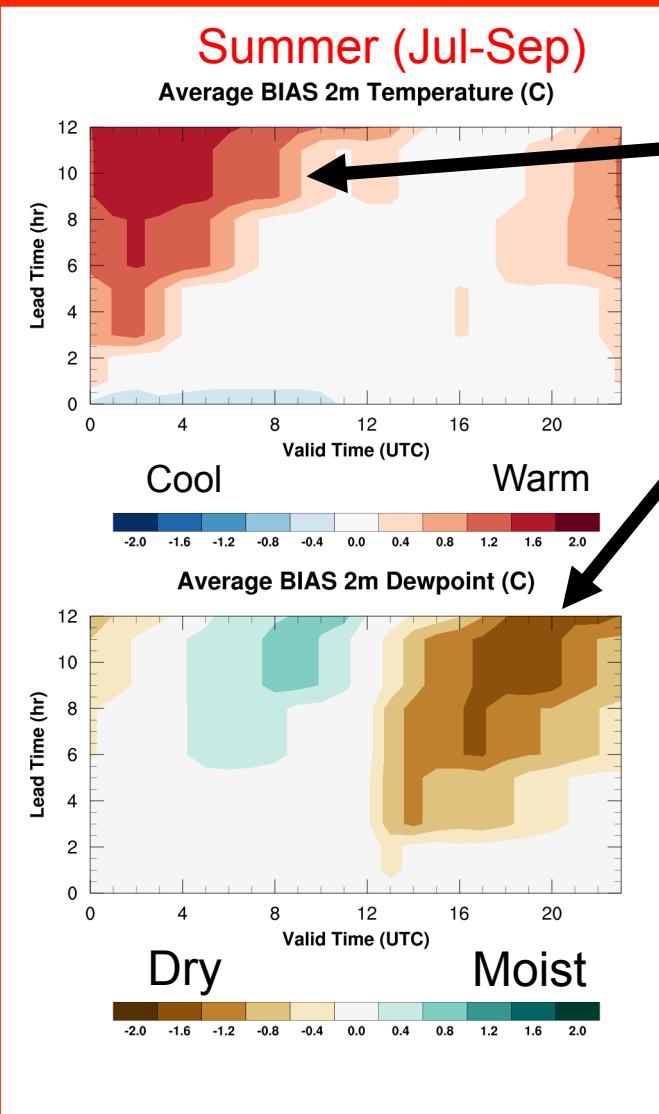
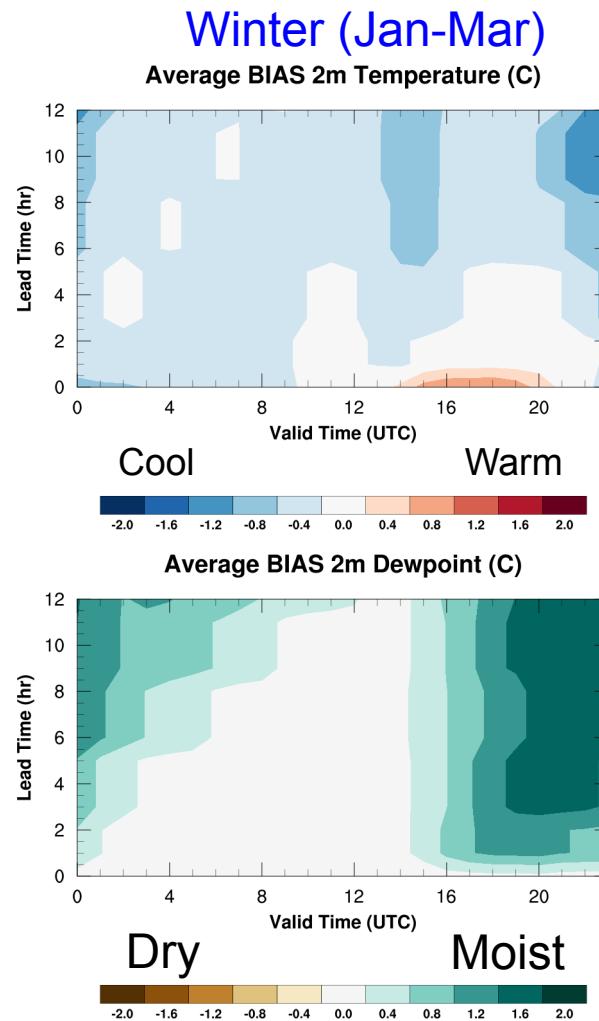
- A problem for convection/ceiling/terminal forecasts

12-h forecasts of downward shortwave flux at surface





RAPv2/HRRRv1 Forecast Biases



The RAP/HRRR has a daytime warm bias in the warm season.

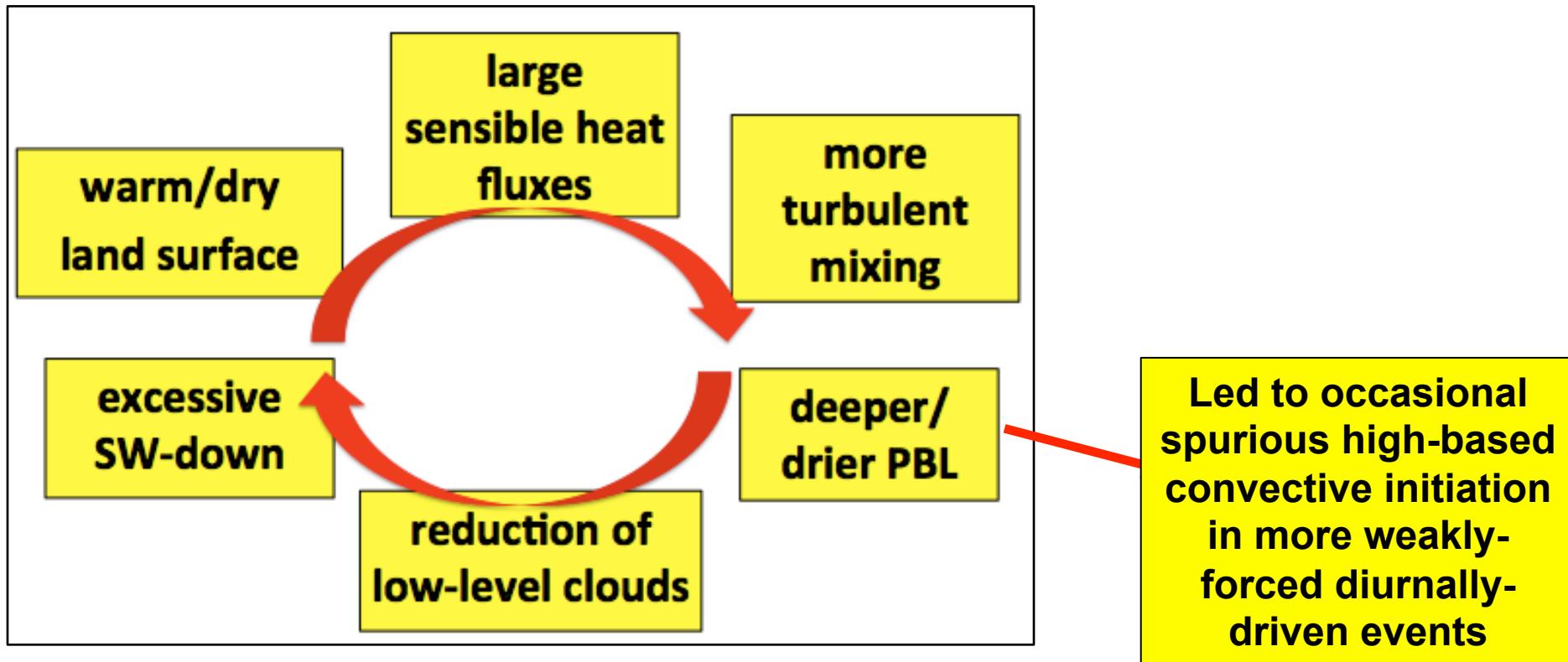
The RAP/HRRR has a daytime dry bias in the warm season.

Experimental improvements to the model to remove bias have been made and will be implemented in RAPv3/HRRRv2.

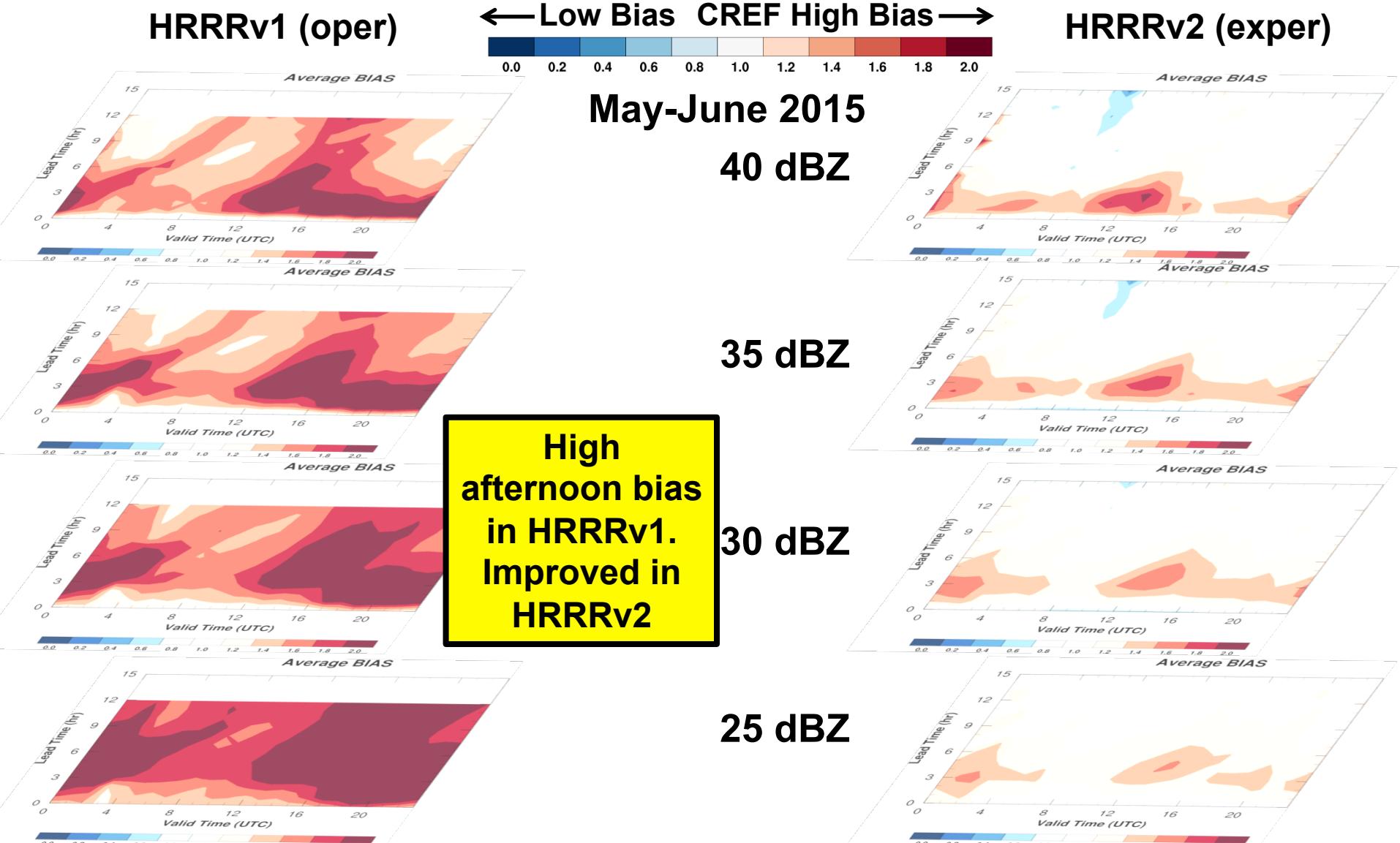


RAPv2/HRRRv1 Model Bias Feedback

Conceptual Model of Positive Feedback Model Bias



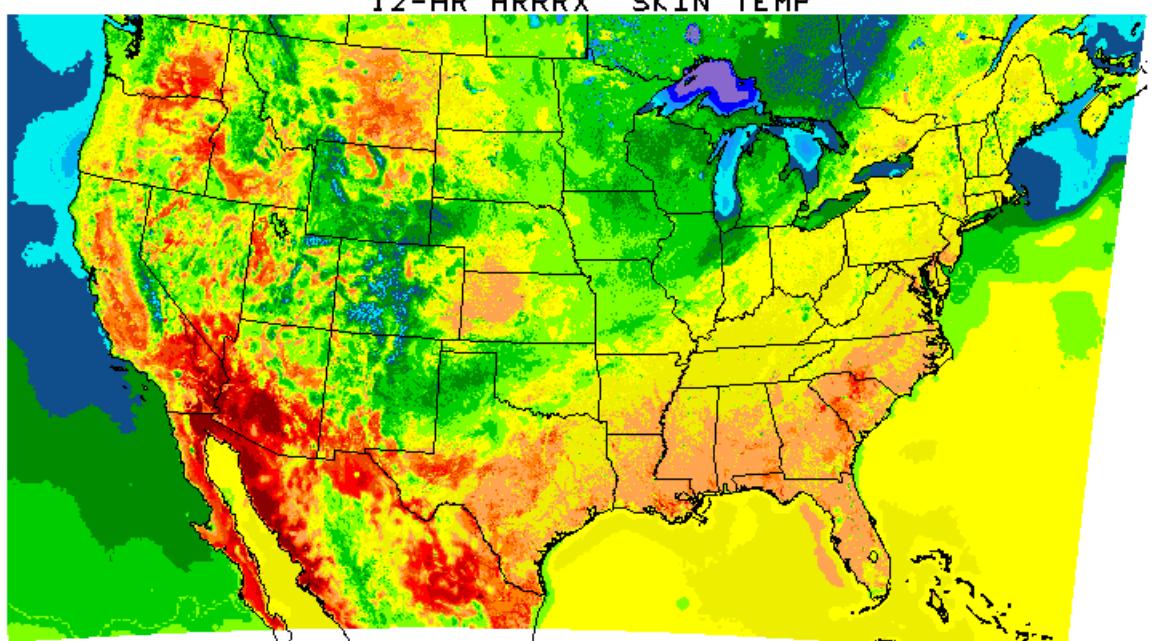
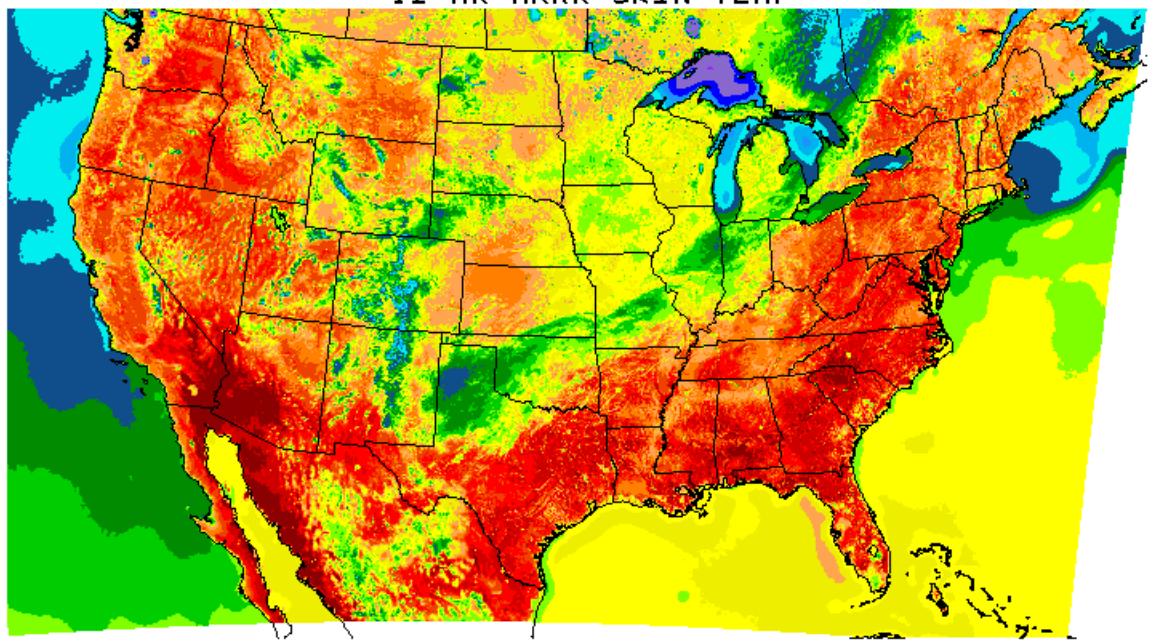
HRRRv1 to v2 Reflectivity Forecast Skill



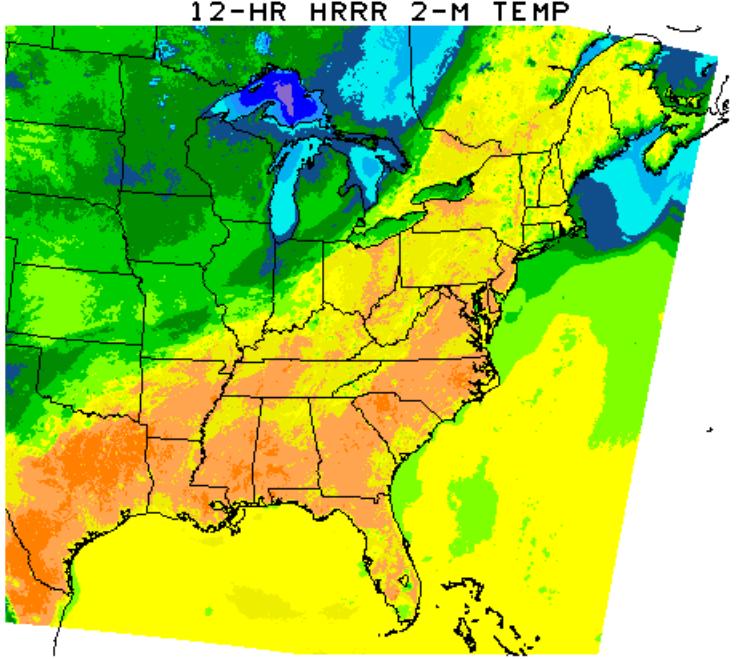


RAPv3/HRRRv2 Warm/Dry Bias Mitigation

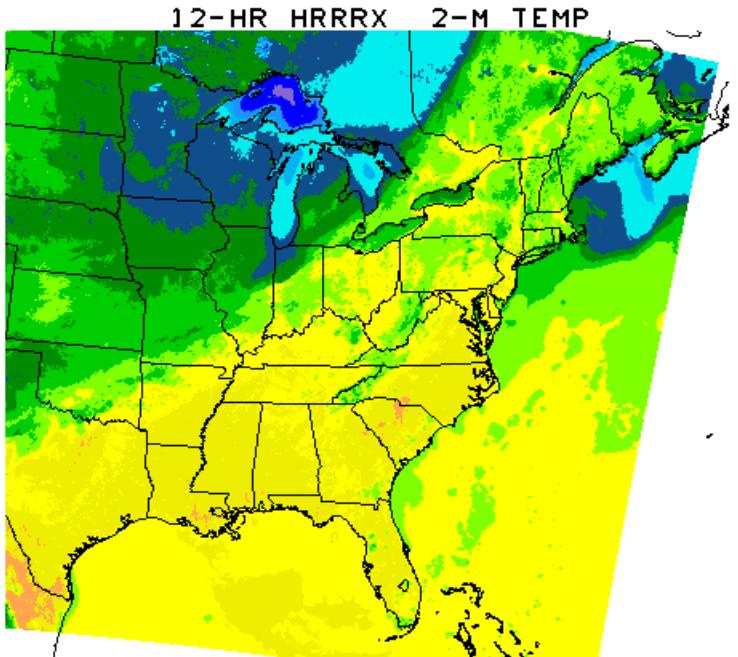
Component	Mitigating Items
GSI Data Assimilation	Canopy water cycling Temp pseudo-innovations thru model boundary layer More consistent use of surface temp/dewpoint data
GFO Convective Parameterization	Shallow cumulus radiation attenuation Improved retention of stratification atop mixed layer
Thompson Microphysics	Aerosol awareness for resolved cloud production Attenuation of shortwave radiation
MYNN Boundary Layer	Mixing length parameter changed Thermal roughness in surface layer changed Coupling boundary layer clouds to RRTMG radiation
RUC Land Surface Model	Reduced wilting point for more transpiration Keep soil moisture in croplands above wilting point



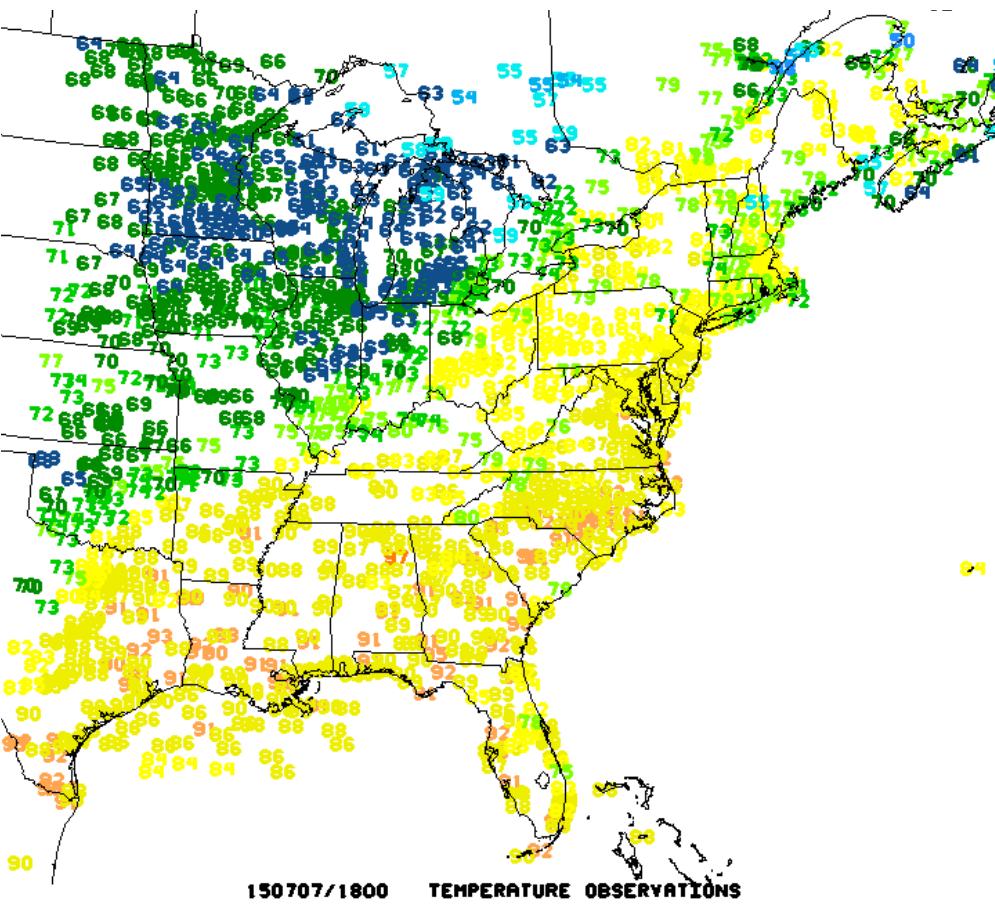
Huge
reductions in
skin temps in
daytime



FCST MADE 06Z 07/07

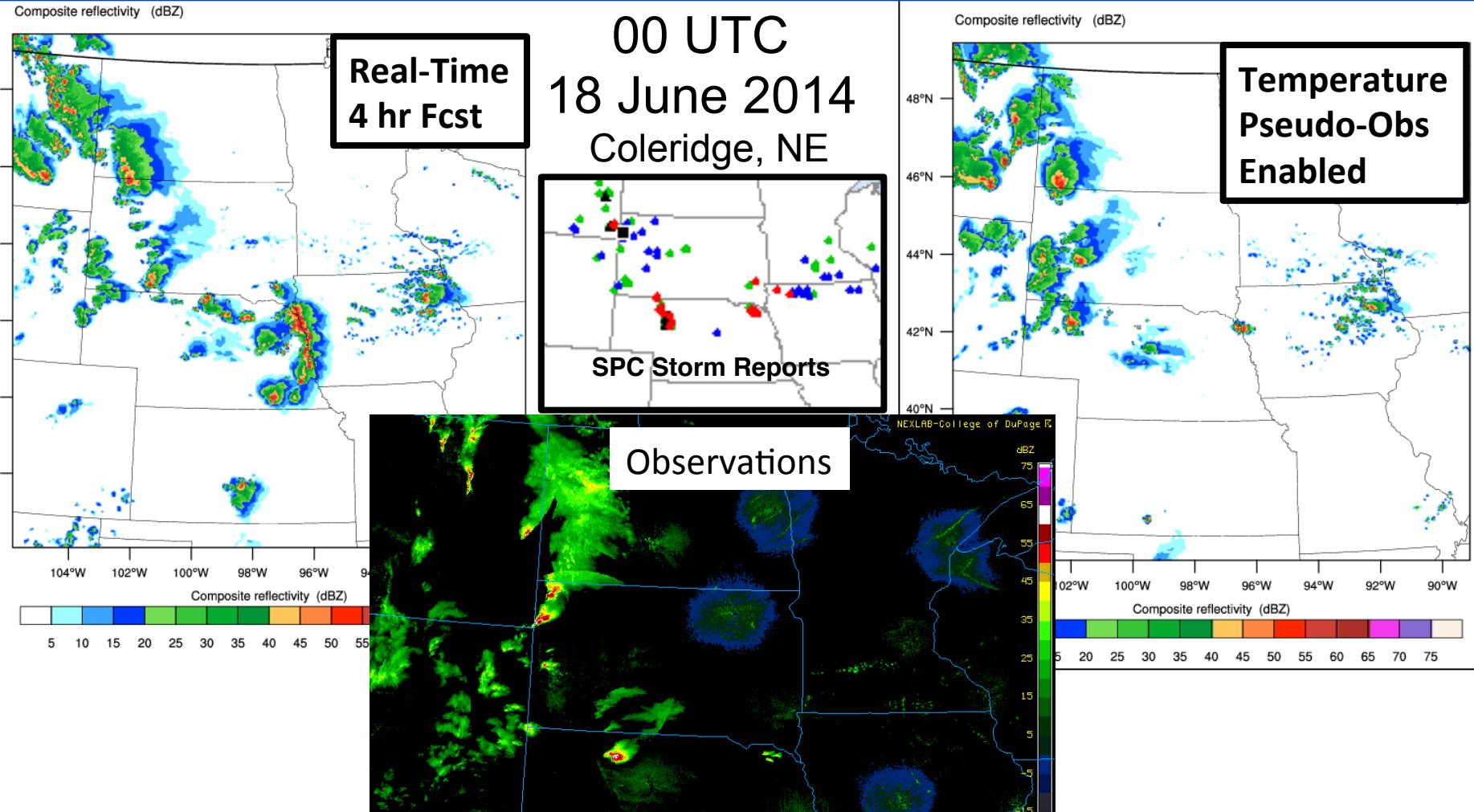


With significant positive impact
on 2-m temps





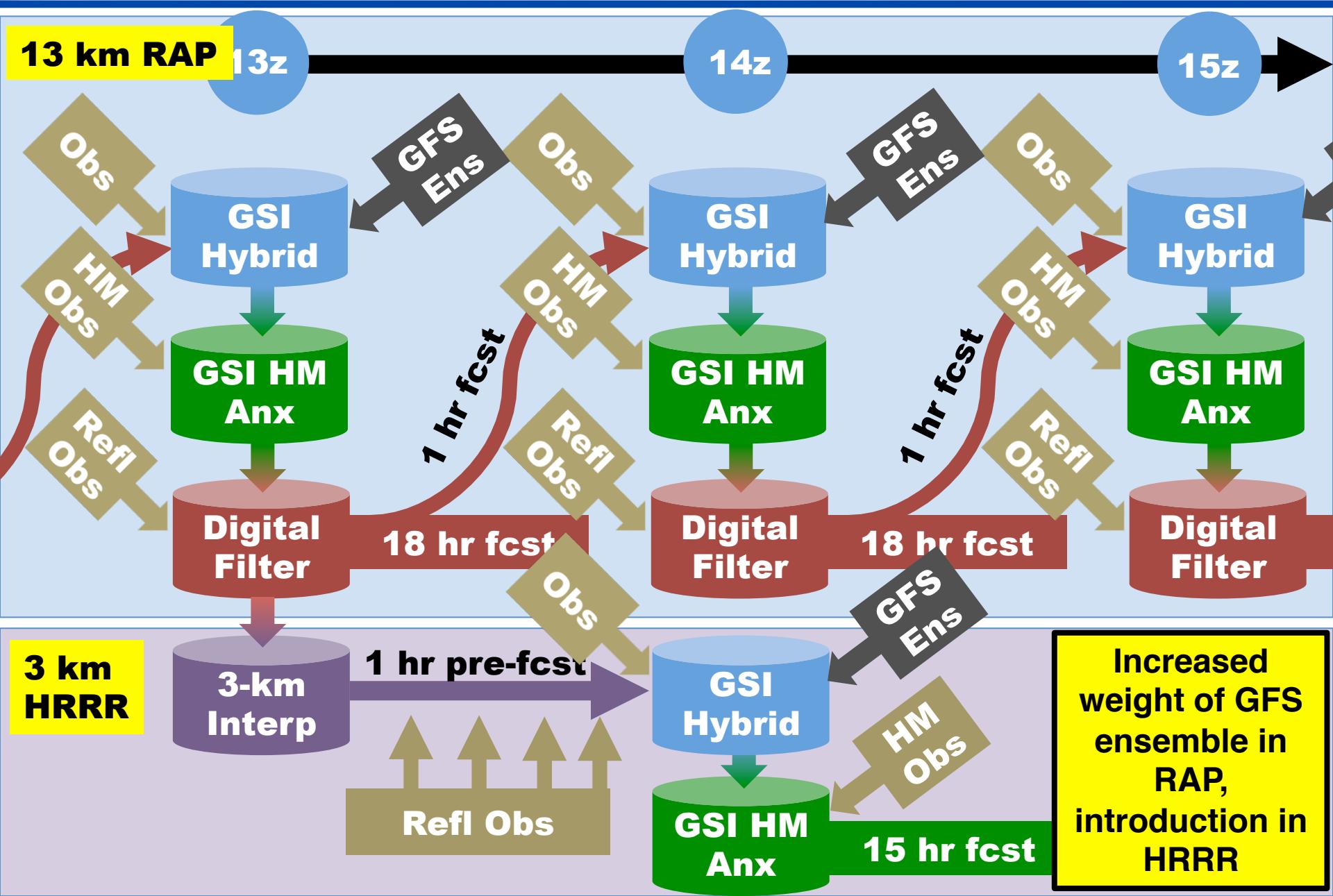
HRRR Convective Case Study



Control run develops too much high-based convection that grows upscale.
Data assimilation change improves timing and evolution of convection.

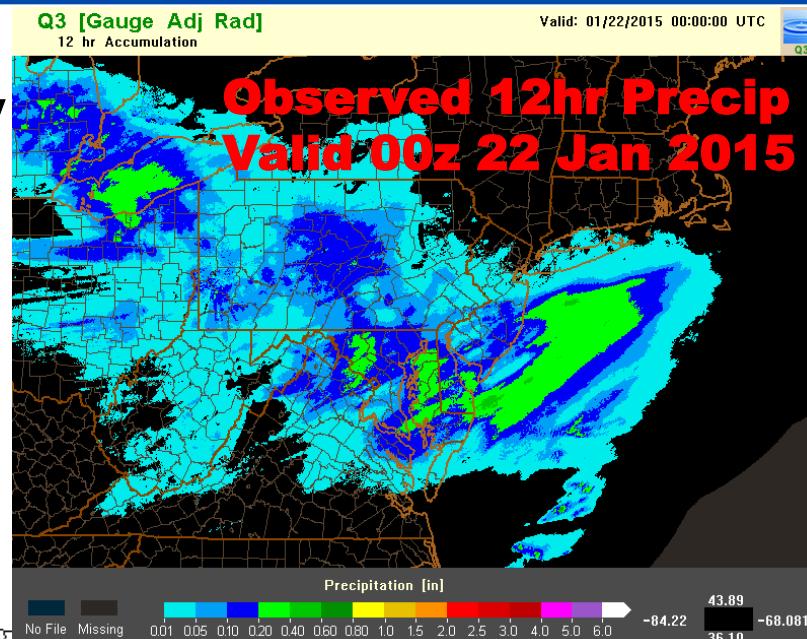


HRRRv2 Initialization from RAPv3



HRRR Winter Case Study

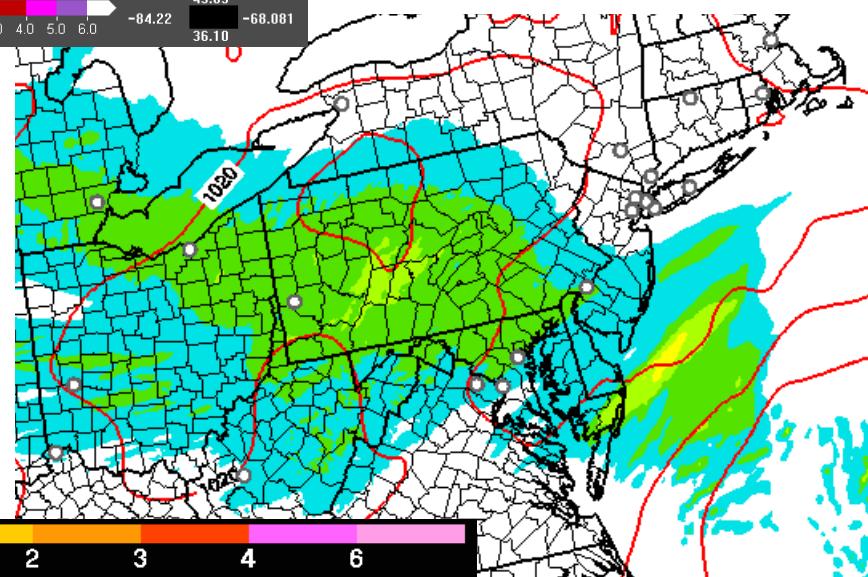
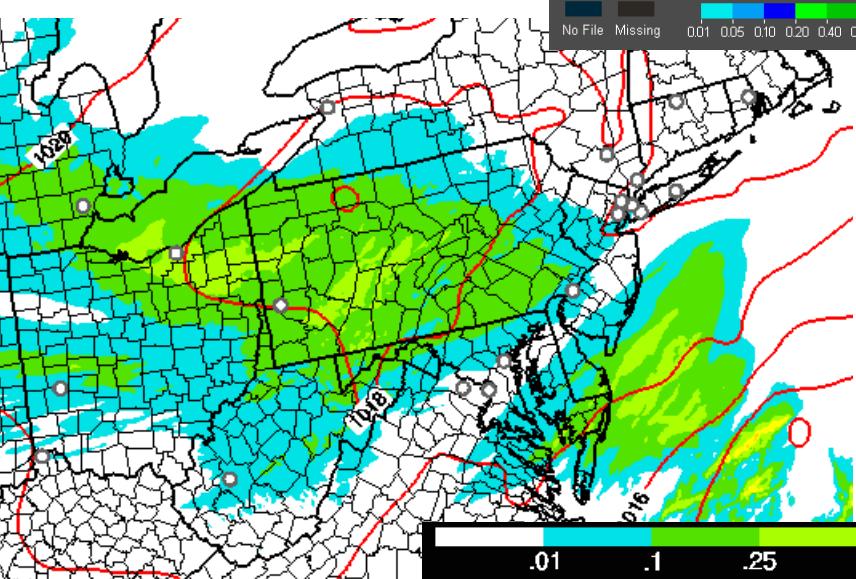
“Clipper” System Produced 1-2” snow D.C. Metro 21 Jan 2015



More precipitation produced in D.C. and northern suburbs

Exper HRRR 12 hr fcst

Valid 00z 22 Jan 2015





Operational RAPv2 and HRRRv1

Model	Run at:	Domain	Grid Points	Grid Spacing	Vertical Levels	Pressure Top	Boundary Conditions	Initialized
RAP	GSD, NCO	North America	758 x 567	13 km	50	10 mb	GFS	Hourly (cycled)
HRRR	GSD, NCO	CONUS	1799 x 1059	3 km	50	20 mb	RAP	Hourly (pre- forecast hour cycle)
Model	Version	Assimilation	Radar DA	Radiation LW/SW	Microphysics	Cumulus Param	PBL	LSM
RAP	WRF-ARW v3.4.1+	GSI Hybrid 3D-VAR/ Ensemble – 0.5	13-km DFI	RRTM/ Goddard	Thompson v3.4.1	G3 + Shallow	MYNN	RUC
HRRR	WRF-ARW v3.4.1+	GSI 3D-VAR	3-km 15-min LH	RRTM/ Goddard	Thompson v3.4.1	None	MYNN	RUC
Model	Horiz/Vert Advection	Scalar Advection	Upper-Level Damping	6 th Order Diffusion	SW Radiation Update	Land Use	MP Tend Limit	Time-Step
RAP	5 th /5 th	Positive- Definite	w-Rayleigh 0.2	Yes 0.12	10 min	MODIS Fractional	0.01 K/s	60 s
HRRR	5 th /5 th	Positive- Definite	w-Rayleigh 0.2	No	5 min	MODIS Fractional	0.07 K/s	20-23 s



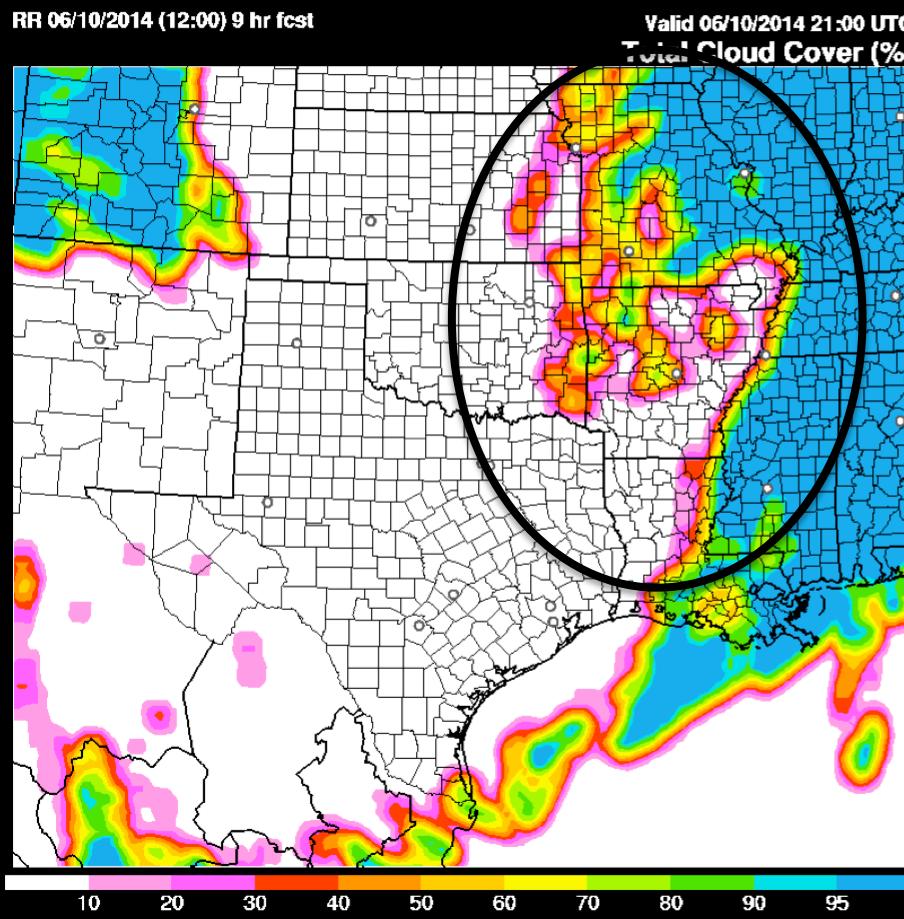
RAPv3 / HRRRv2 – 2015 Changes

Model	Run at:	Domain	Grid Points	Grid Spacing	Vertical Levels	Pressure Top	Boundary Conditions	Initialized
RAP	GSD, NCEP	North America	953 x 834	13 km	50	10 mb	GFS	Hourly (cycled)
HRRR	GSD, NCEP	CONUS	1799 x 1059	3 km	50	20 mb	RAP	Hourly (pre- forecast hour cycle, LSM full)
Model	Version	Assimilation	Radar DA	Radiation LW/SW	Microphysics	Cumulus Param	PBL	LSM
RAP	WRF-ARW v3.6+	GSI Hybrid 3D-VAR/ Ensemble to 0.75	13-km DFI + low reflect	RRTMG/ RRTMG	Thompson – aerosol v3.6.1	GFO v3.6+	MYNN v3.6+	RUC v3.6+
HRRR	WRF-ARW v3.6+	3km: GSI Hybrid 3D- VAR/Ensemble to 0.75	3-km 15-min LH +low reflect	RRTMG/ RRTMG	Thompson – aerosol v3.6.1	MYNN PBL Clouds	MYNN v3.6+	RUC v3.6+
Model	Horiz/Vert Advection	Scalar Advection	Upper-Level Damping	6 th Order Diffusion	SW Radiation Update	Land Use	MP Tend Limit	Time-Step
RAP	5 th /5 th	Positive- Definite	w-Rayleigh 0.2	Yes 0.12	20 min	MODIS Fractional	0.01 K/s	60 s
HRRR	5 th /5 th	Positive- Definite	w-Rayleigh 0.2	Yes 0.25 (flat terr)	15 min with SW- dt (Ruiz-Arias)	MODIS Fractional	0.07 K/s	20 s

RAPv3/HRRRv2-2015 Changes

Use of forecast aerosol fields
to have prognostic cloud-
condensation nuclei (CCN).

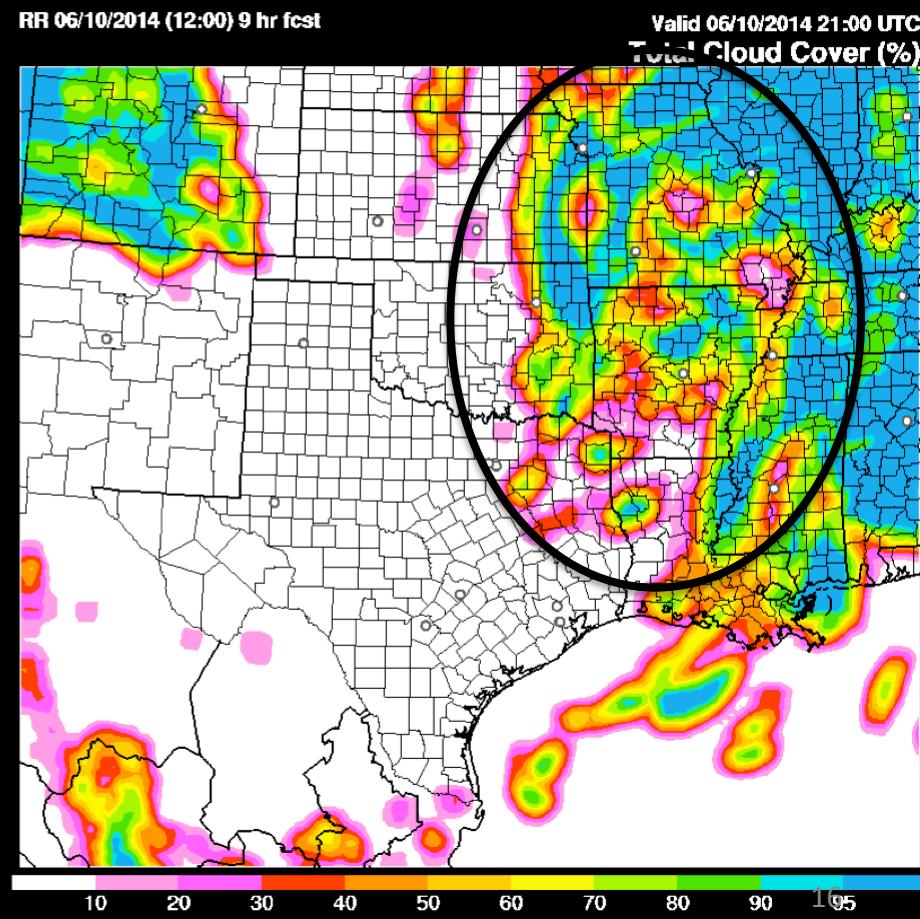
WRFv3.5.1 aerosol unaware



Example: RAP cold-start tests without/with aerosol-aware cloud microphysics.

More small-scale cloud with more CCN over land.

WRFv3.6 Aerosol-aware





RAPv3 Retrospective Verification

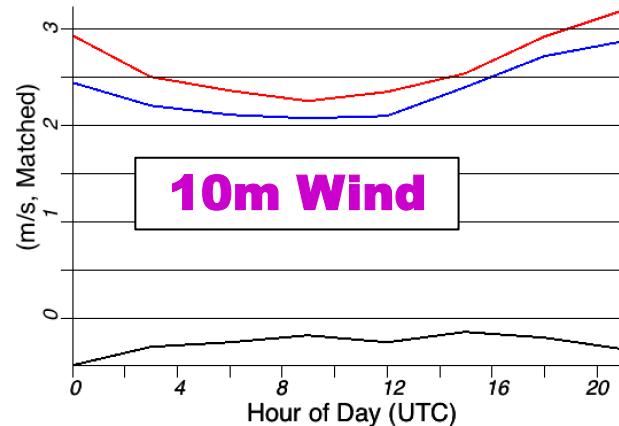
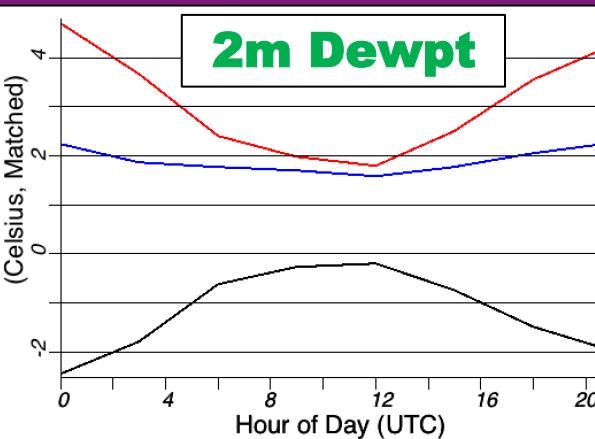
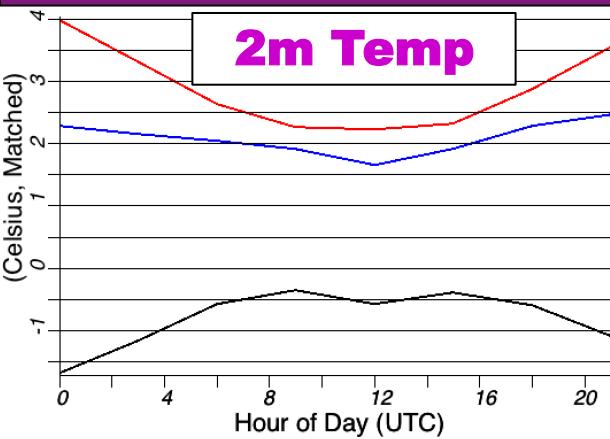
Eastern US 15 Jul – 15 Aug 2014

Exper RAPv3

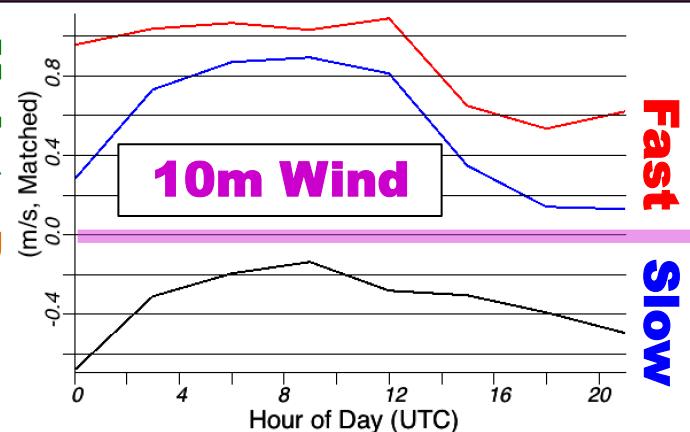
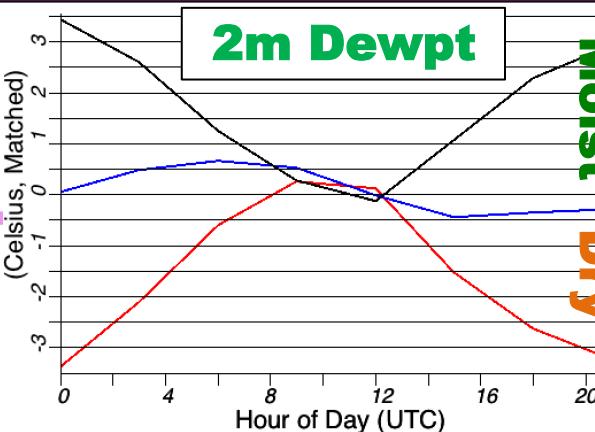
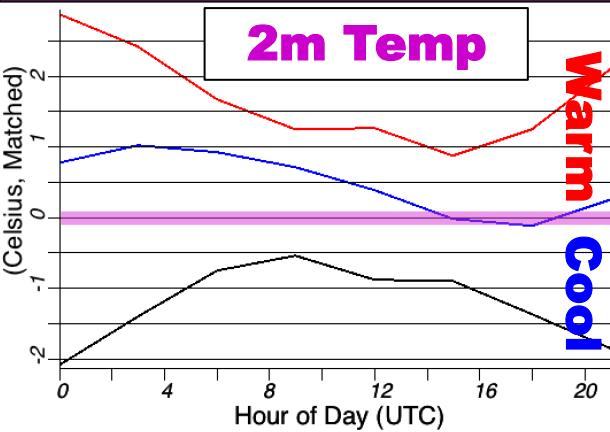
Oper RAPv2

RAPv3 - RAPv2 Difference

RAP Surface 12-hr Forecast RMSE



RAP Surface 12-hr Forecast Bias



Reduced warm bias

Reduced dry bias

Reduced fast bias



RAPv3 Retrospective Verification

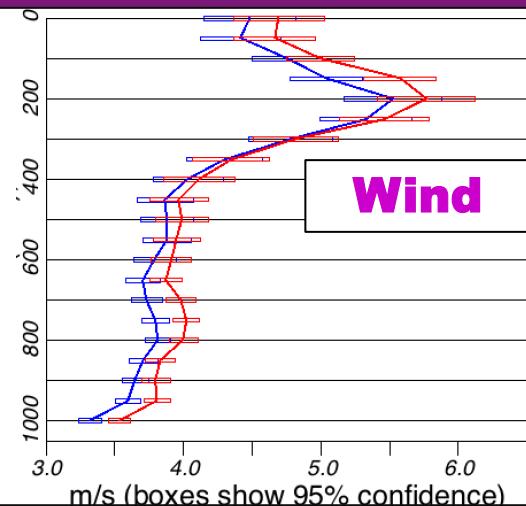
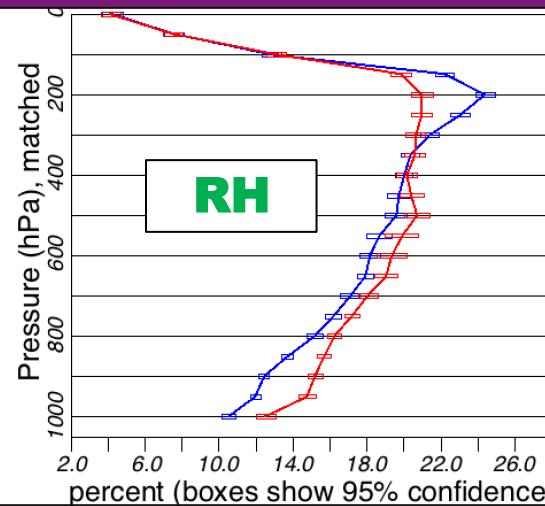
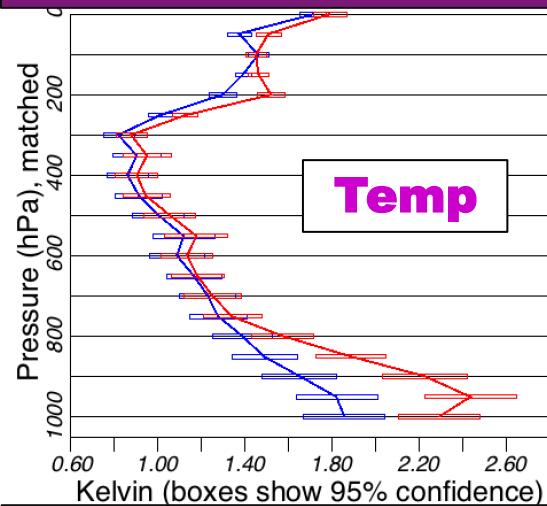
US 15 Jul – 15 Aug 2014

Exper RAPv3

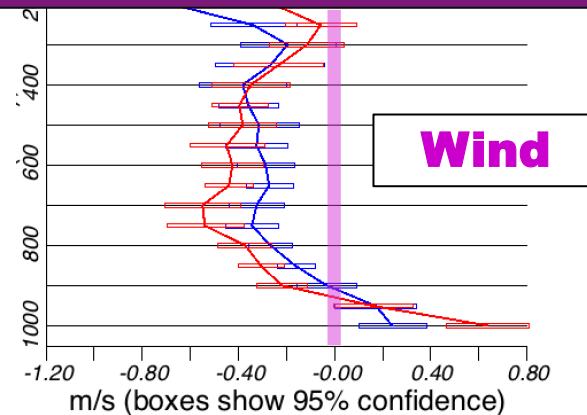
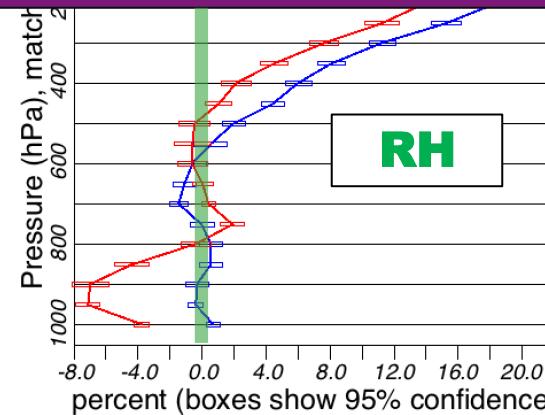
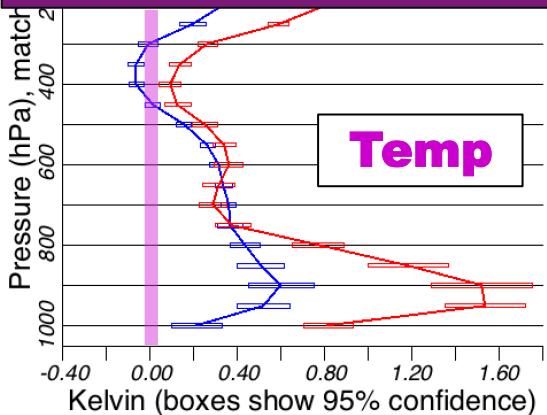
Oper RAPv2

RAPv3 - RAPv2 Difference

RAP Upper-Air 12-hr Forecast RMSE



RAP Upper-Air 12-hr Forecast BIAS (00 UTC Only)





RAPv3 Retrospective Verification

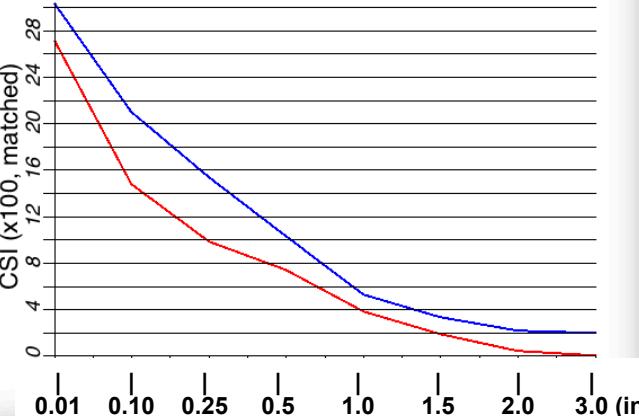
Eastern US 15 Jul – 15 Aug 2014

Exper RAPv3

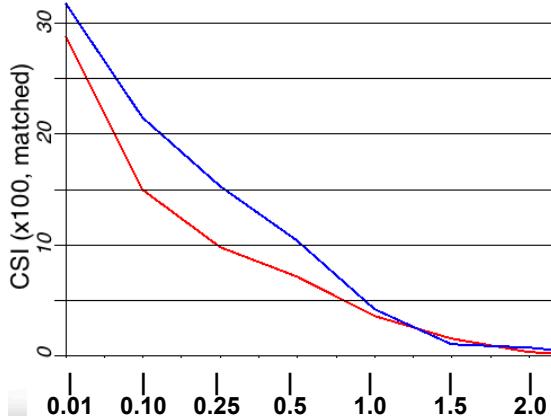
Oper RAPv2

RAP Eastern US Precipitation 6-hr Forecast

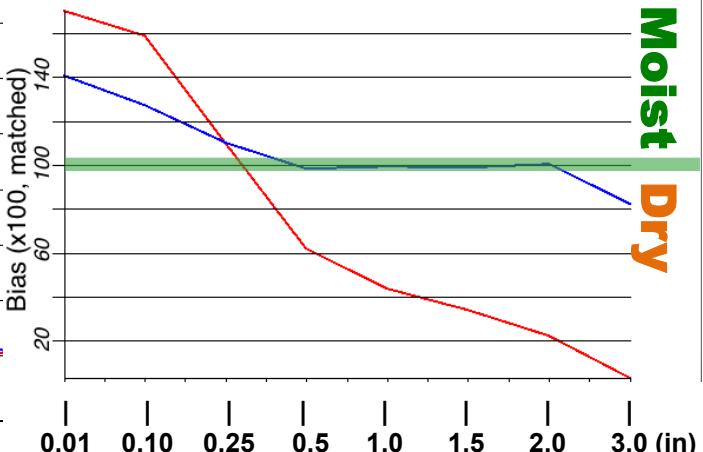
CSI 13-km



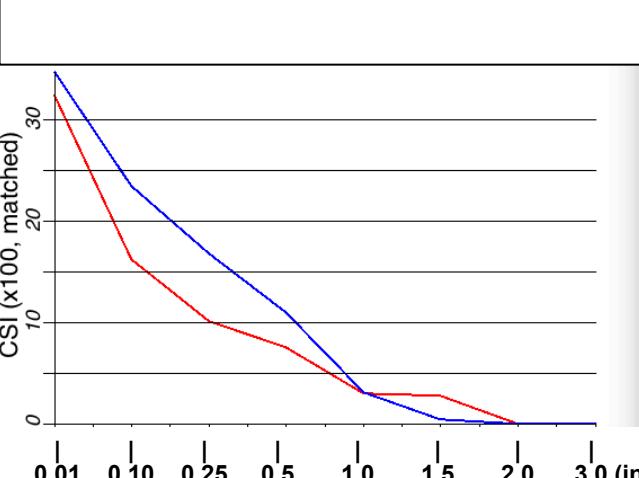
CSI 20-km



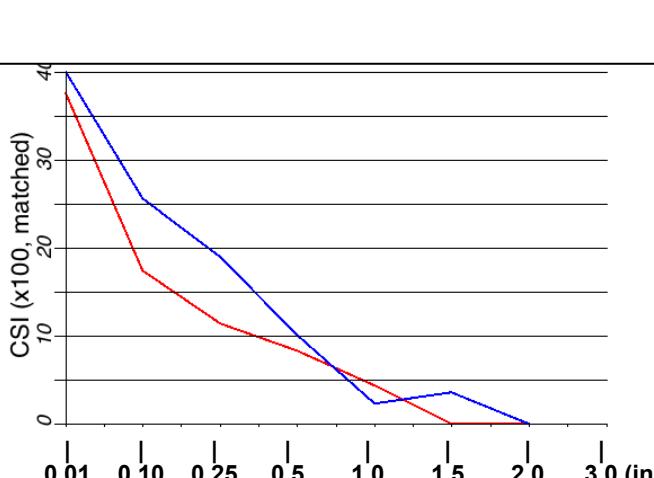
BIAS 13-km



CSI 40-km



CSI 80-km



Reduced moist bias
at low precip
thresholds

Reduced dry bias at
high precip
thresholds

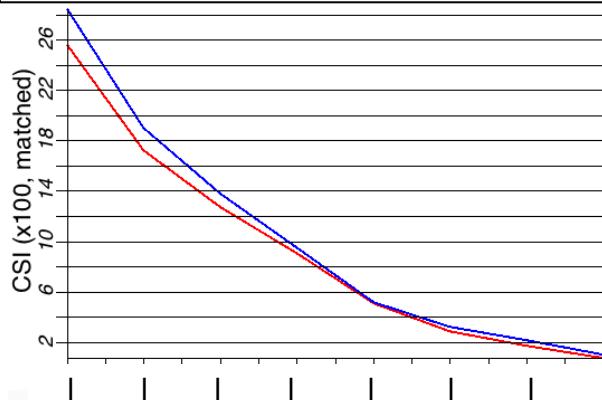


HRRRv2 Retrospective Verification

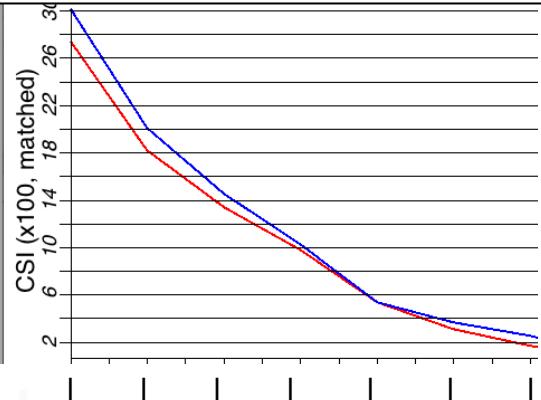
15 Jul – 15 Aug 2014 Exper HRRRv2 Real-time HRRR

HRRR Eastern US Precipitation 6-hr Forecast

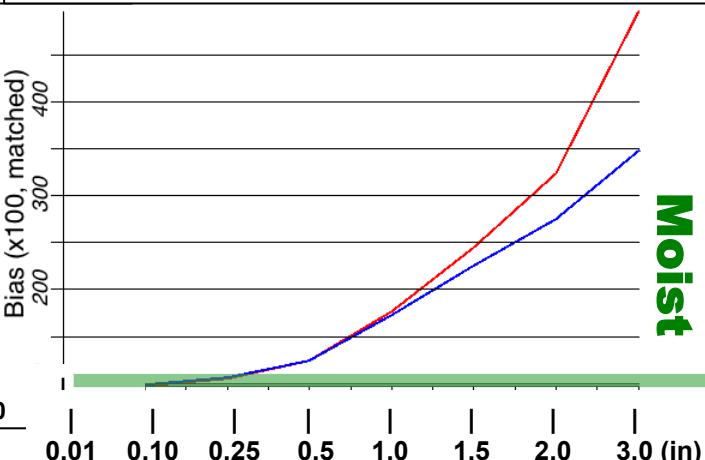
CSI 3-km



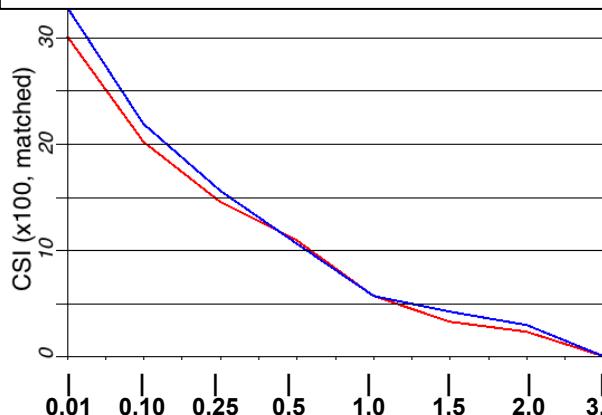
CSI 20-km



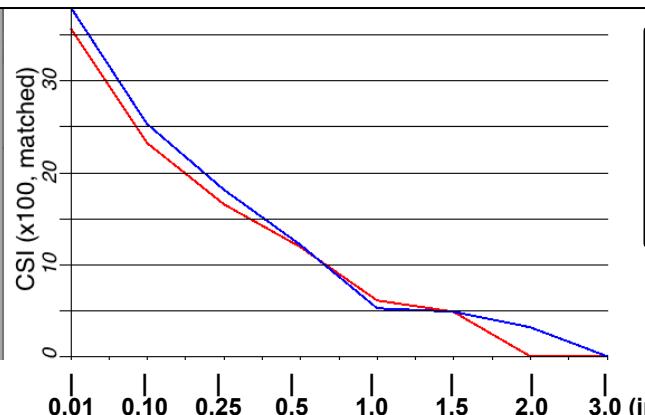
BIAS 3-km



CSI 40-km



CSI 80-km



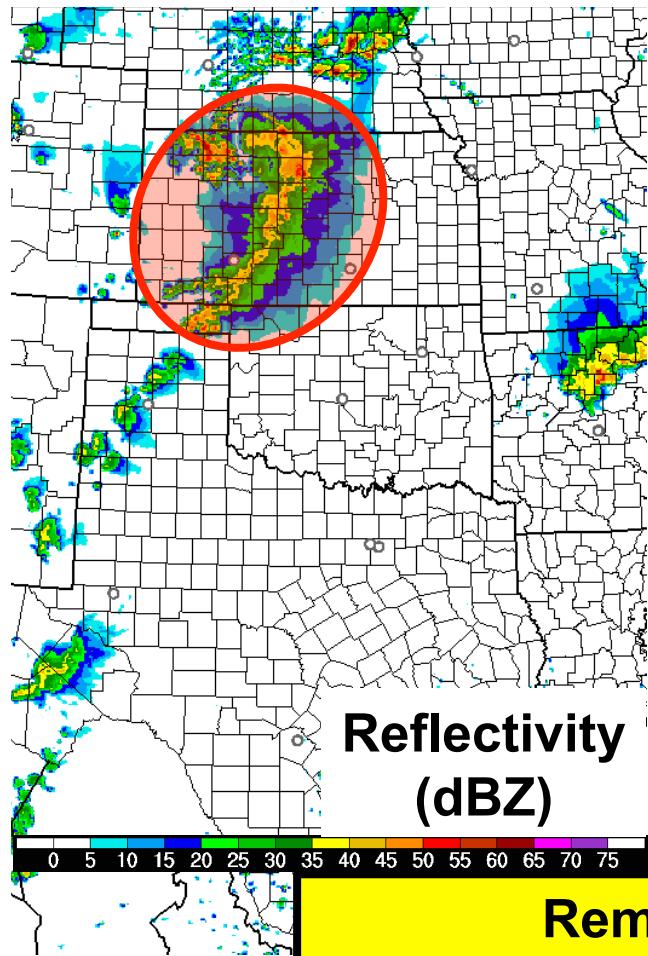
Reduced moist bias
at high precip
thresholds



HRRR Convective Case Study

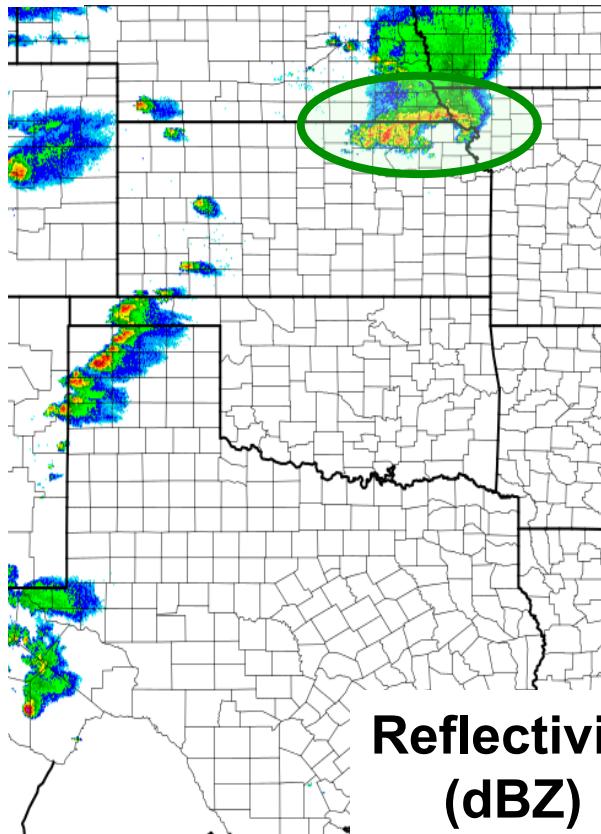
Operational

HRRRv1 06hr Fcst



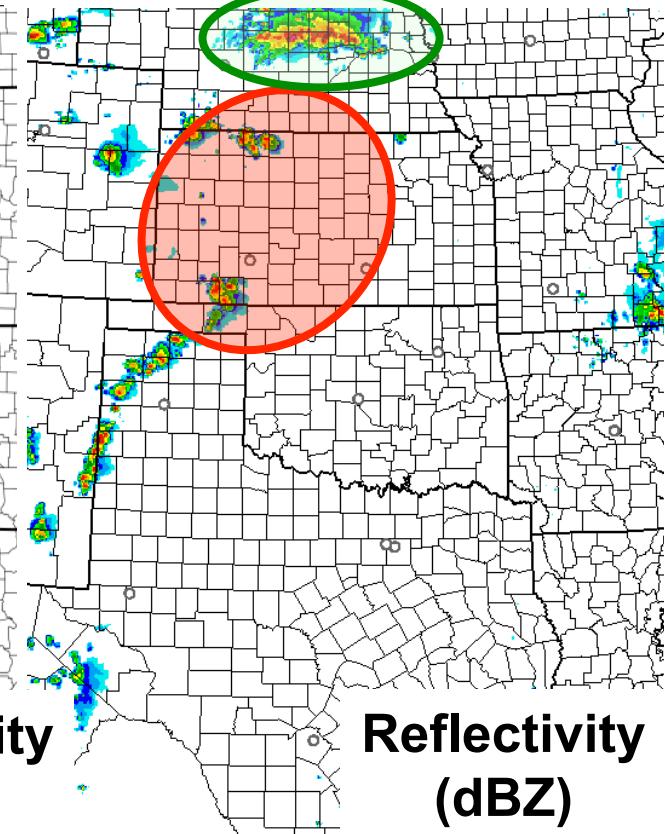
Observations

00z 05 June 2015



Experimental

HRRRv2 06hr Fcst



Reflectivity
(dBZ)

Reflectivity
(dBZ)

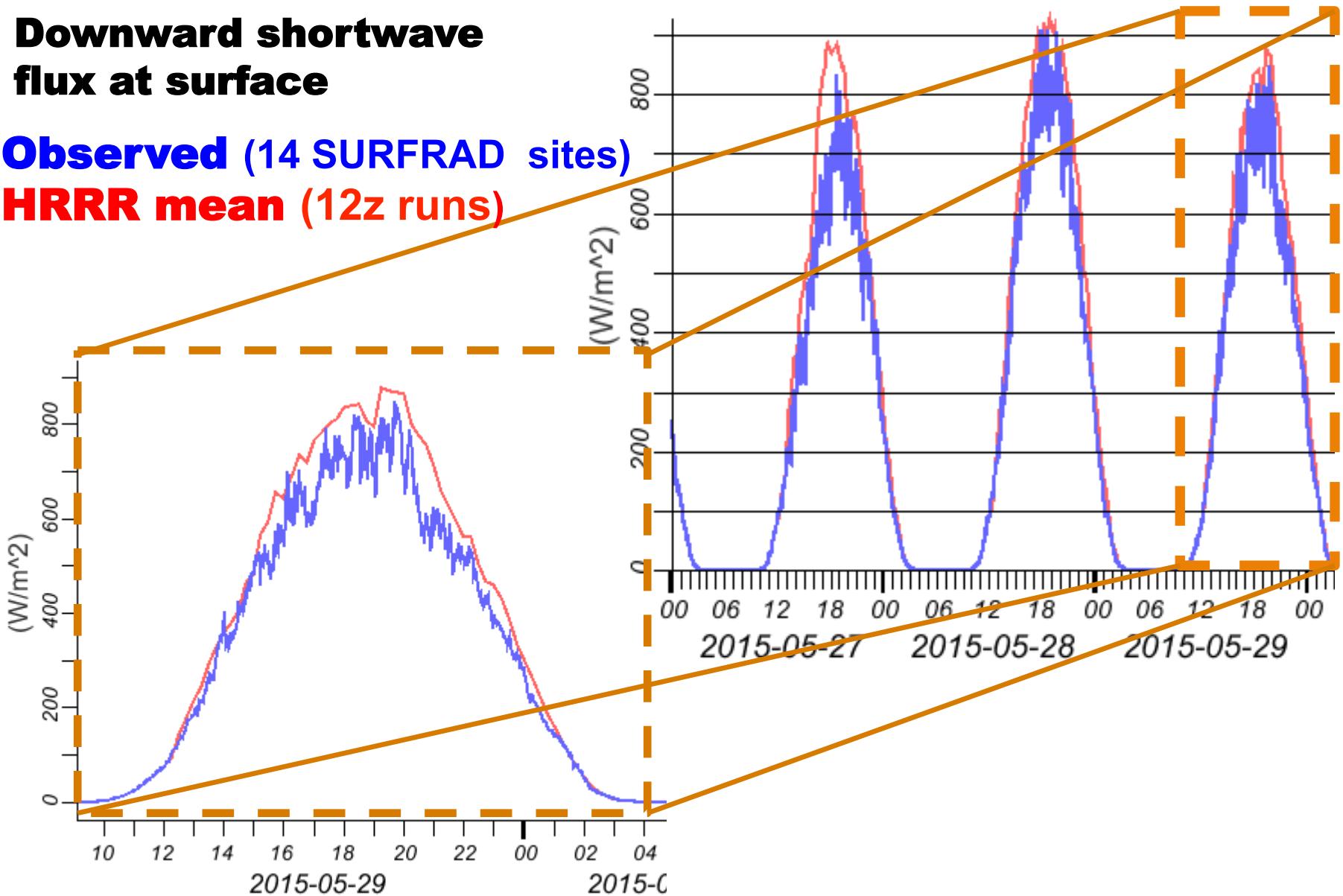
Reflectivity
(dBZ)

Removal of false alarm convection
More accurate evolution of observed convection

15-min Validation of HRRR forecasts

Downward shortwave flux at surface

Observed (14 SURFRAD sites)
HRRR mean (12z runs)



Winds -- Consistent RAPv3 improvement for both upper-air and surface, for all seasons

Temperature – Reduced low-level warm bias for warm season afternoon / evening. Improved upper-level temperature forecasts

Moisture – Reduced low-level dry bias for warm season afternoon / evening. Improved upper-level relative humidity forecast

Precipitation – Slight improvement, reduced low thresh high bias / increased high thresh low bias



RAP/HRRR Implementation Map

ESRL – experimental version

NWS-NCEP - operational

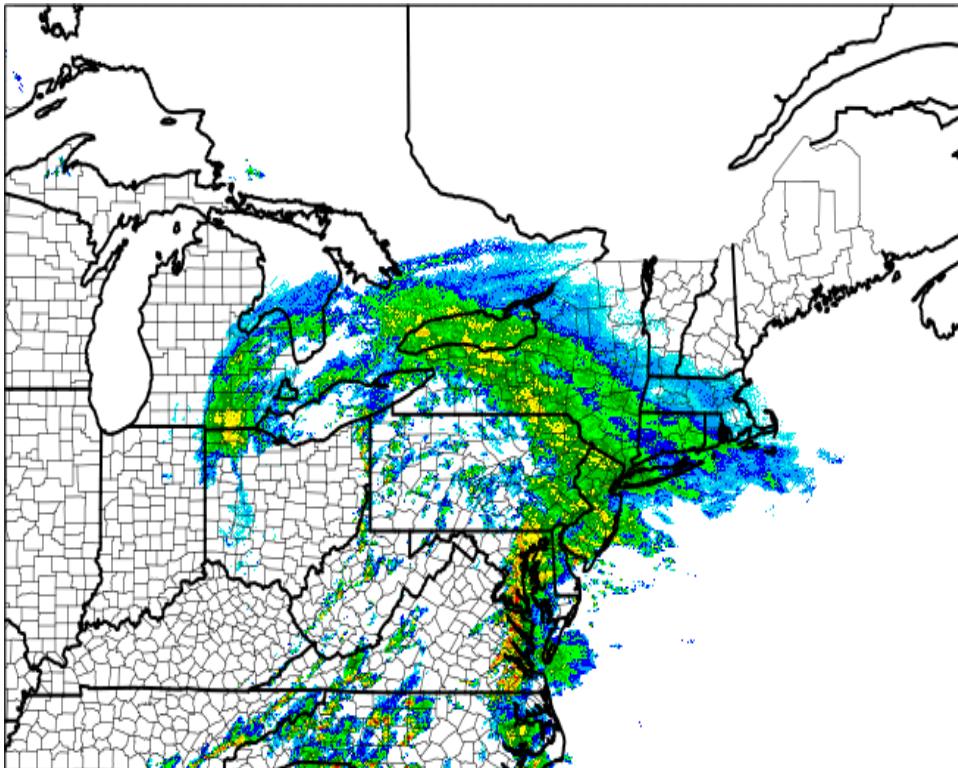
- RAPv3 – GSD testing in 2014-15 → • Implement early 2016
 - Is initializing 2015 ESRL-HRRR(v2)
 - Improved PBL, LSM, cu-parm, DA
 - WRFv3.6.1 w/ Thompson/NCAR aerosol-aware microphysics
- HRRRv2 – GSD testing in 2014-15 → • Implement early 2016
 - Initialized by 2015 RAP (v3)
 - Improved radar assimilation, hybrid assimilation, PBL/cloud physics
- RAPv4 – GSD testing in 2016 → • Implement 2017
 - Hourly RAP ensemble data assimilation
- HRRRv3 – GSD testing in 2016 → • Implement 2017
 - Improved 3km physics
 - Full 3-km hourly cycling w/radial vel
 - Cycling of aerosols with fire/emissions



Experimental RAP/HRRR 24hr Fcst Length

Observations

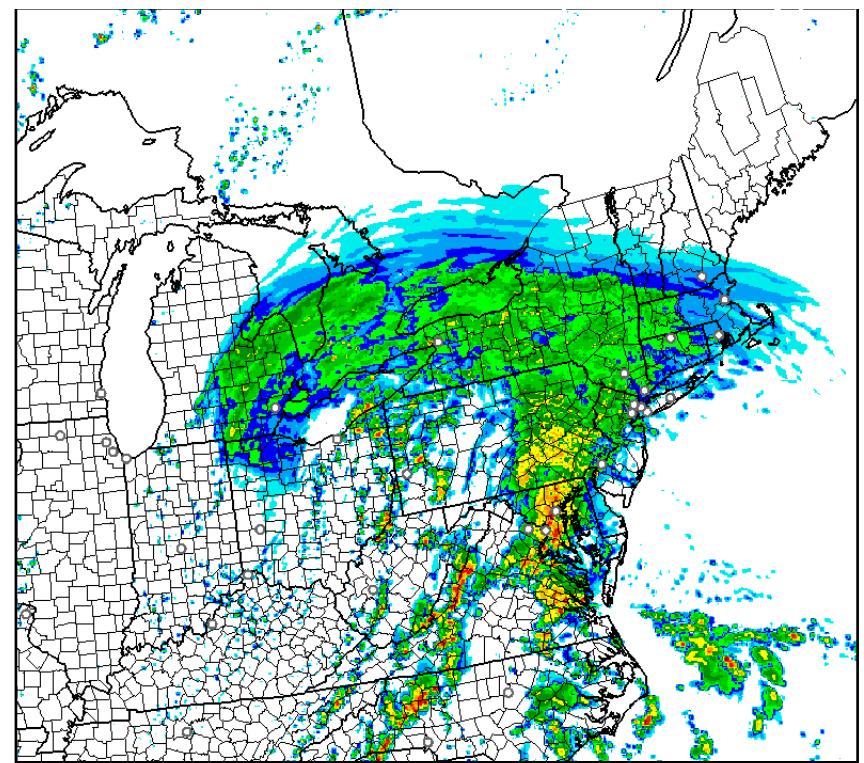
21z 27 June 2015



<http://rapidrefresh.noaa.gov/HRRR> (24 hrs)

<http://rapidrefresh.noaa.gov/RAP> (30 hrs)

Exper HRRRv2 21hr Fcst

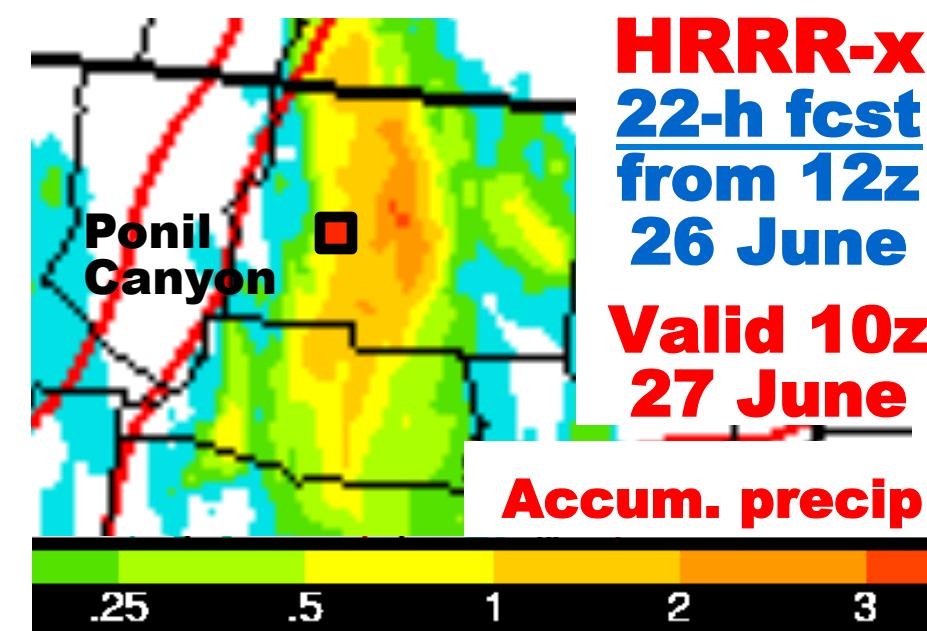
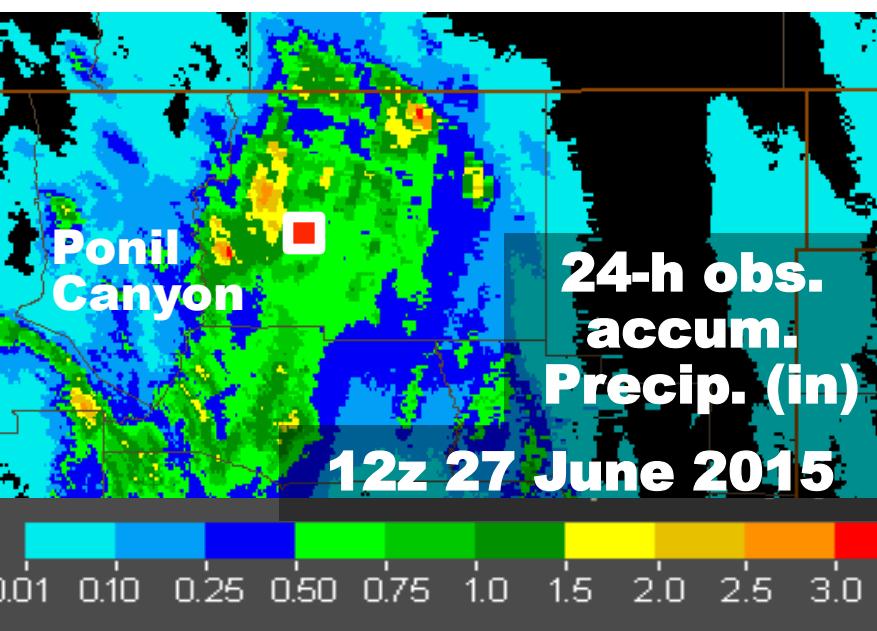
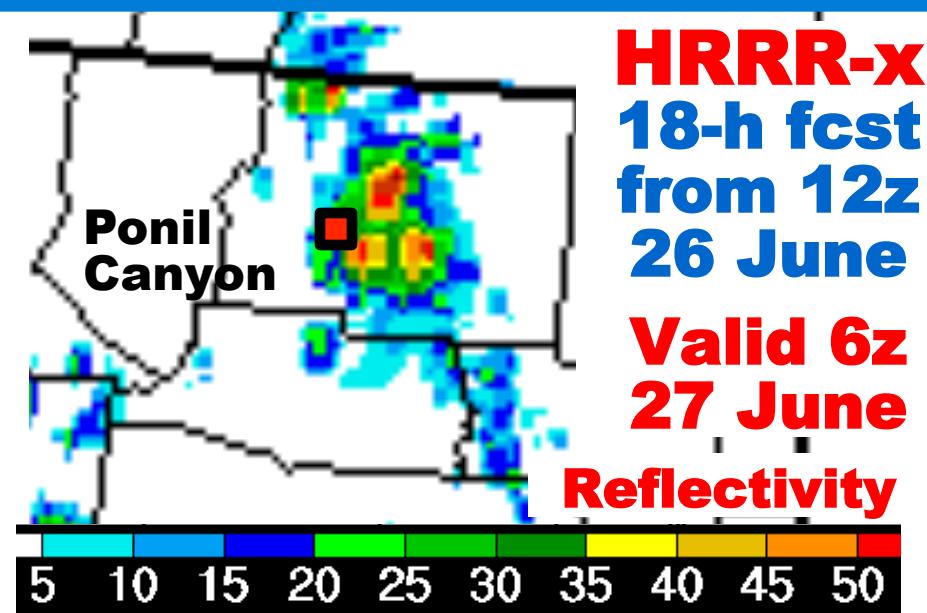
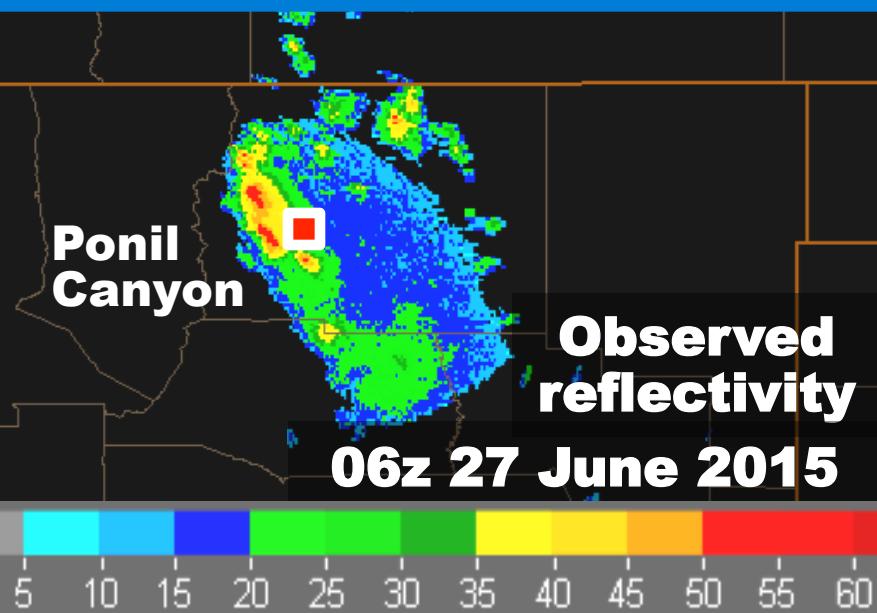


Longer forecasts to cover Day One forecast products (WPC, SPC...)

Longer lead-time forecasts for high-impact events.

More members in time-lagged ensemble.

Philmont Scout Ranch Flash Flood Fatality



Philmont Scout Ranch Flash Flood Fatality

